

THE ANNALS

AND

MAGAZINE OF NATURAL HISTORY.

[THIRD SERIES.]

No. 72. DECEMBER 1863.

XLI.—*On Polytrema miniaceum, a Polythalamian.*

By PROFESSOR MAX SCHULTZE*.

[Plate VII. figs. 1-10.]

UNDER the name of *Polytrema corallina*, Risso† describes certain small, red, coral-like calcareous structures which occur pretty widely in the Mediterranean upon seaweeds, shells, and other marine productions. They form calcareous crusts, measuring 3-4 millims. or less in their greatest diameter, of a dingy carmine-red colour, and with an irregular surface; they adhere firmly usually to a flat surface, but are also frequently met with forming rings round thin stems of Algæ.

These structures resemble small Millepores, with which indeed they were formerly placed. Linnæus's *Millepora miniacea*‡ must be referred to our species. Lamarck describes them as *Millepora rubra*§, whilst De Blainville|| combined Risso's generic name *Polytrema* with the Linnæan specific name *miniacea* (or, more properly, *miniaceum*), which appellation is here adopted.

On the surface of these structures the lens shows numerous roundish shallow depressions, which extend equally over the lobed or cock'scomb-like elevations and over the depressed parts between these. (Pl. VII. fig. 1). The depressions are usually very shallow, and are occupied at the bottom by precisely the same mass which is seen between them. Frequently the bottom of the little depressions rises in the form of a somewhat spherical dome, like a mountain cone ascending from the depths of a crater and gradually filling the latter completely.

* Translated by W. S. Dallas, F.L.S., from Wiegmann's Archiv, 1863, p. 81.

† Hist. Nat. Eur. Mérid. v. p. 340.

‡ Systema Naturæ, ed. Gmel. vi. p. 3784.

§ Hist. Nat. Anim. sans Vert. || Man. d'Actin. p. 410, pl. 69. fig. 4.

The apices of the lobes and combs of the surface also bear similar shallow depressions. But, on these, orifices passing further inwards are very frequently met with—the commencement of canals which penetrate the interior. These orifices I do not regard as natural, but as produced by the breaking off of the processes or by the erosion of the surface.

Dr. Krohn had the kindness to give me some *Polytremata* which he had collected on seaweeds at Nice and brought with him in a dry state. At the first glance of these I was vividly reminded of the Polythalamian structures from the Philippines, described by me as *Acervulina acinosa**, which are of the same size and colour, and occur under similar circumstances, but present a somewhat different relief on the surface. Krohn had already ascertained that *Polytrema* exhibits a structure of the calcareous walls similar to that presented by the thick-walled Polythalamian shells. But what had especially attracted his attention was, that in *Polytrema* it appeared that *siliceous spicules* occurred constantly, as in the Sponges, sometimes projecting freely from the above-mentioned orifices at the apices of the lobes, but in other cases only becoming visible when the calcareous shell was crushed.

The examination of the dry specimens given to me at once confirmed the similarity of the structure of the calcareous walls with that of the thick-walled Polythalamian shells, and at the same time the occurrence of sponge-spicules in the interior of the *Polytrema*. These were chiefly siliceous, and exactly of the structure of ordinary sponge-spicules, awl-shaped, with a fine axial canal, and either pointed at both ends or knobbed at one of them. (Pl. VII, fig. 10.) A few calcareous spicules were intermixed with them, as could be ascertained at once, and without chemical tests, by means of the polarizing apparatus. Very small spicules, hooked at both ends, also occur (fig. 10 a). Of any organic matter occupying the cavity the dried specimens showed mere traces.

The interest attaching to the structures under investigation could not but be extraordinarily increased when it appeared, from further inquiry into the literature of the subject, that very nearly allied structures had been examined by Dr. Gray, and placed as intermediate forms between the Rhizopoda (Foraminifera) and Sponges. Gray found structures resembling *Polytrema* adhering to various marine productions (corals and shells), and published descriptions of them under two new generic names, *Carpenteria* and *Dujardinia*†. By the examination of thin sections of the calcareous shells of these parasitic organisms,

* Ueber den Organismus der Polythalamien, p. 68.

† Ann. & Mag. Nat. Hist. ser. 3. vol. ii. p. 381 (1858).

Carpenter had proved their Foraminiferous nature; but, as sponge-spicules occurred in their chambers, Gray regarded the structures as transitional forms between Foraminifera and Sponges. Gray also met with the *Polytrema miniaceum* of the Mediterranean, but leaves it doubtful whether this is to be arranged with the Foraminifera or with the Bryozoa near *Cribrillina*. He gives it the new name of *Pustularia rosea**.

At Gray's request, Carpenter then more fully investigated the structures arranged in the genus *Carpenteria*, and published a memoir upon them in the 'Philosophical Transactions' for 1860 (vol. cl. pp. 564 *et seq.*), in which he also mentions the *Polytrema miniaceum* of De Blainville as an organism which possesses a Foraminiferous structure of the calcareous shell, and is most nearly allied to the genus *Tinoporus* (p. 561). Carpenter found the sponge-spicules constantly in the chambers of the Polythalamian named after him, and intimates his adhesion to Gray's view that it is a transition form between Foraminifera and Sponges.

Whether we regard Sponges as animals or plants, the occurrence of transition forms between them and the Polythalamia must, under any circumstances, be in the highest degree interesting. An organism of the nature of the Rhizopod-body is supposed to produce simultaneously an external calcareous shell and an internal framework of siliceous spicules. The Sponge-structure, the characteristics of which consist in a much higher histological differentiation of the living substance than appears to occur in the Polythalamia, is supposed to pair with the simple protoplasm-body, not divisible into cells, of the calcareous-shelled Rhizopoda. The affair evidently deserved the most thorough consideration and the most careful testing; there was a fundamental importance attaching to it. For this reason, it was with much pleasure that I found amongst the spirit-specimens collected, in the summer of 1861, by Prof. de la Valette, for the Anatomical Museum of this place, a Crab and a tube of *Vermetus* covered with numerous specimens of the same *Polytrema miniaceum* which I had previously examined in the dry state. As these specimens contained sponge-spicules and also exhibited the organic contents of the chambers in a very perfect state of preservation, I resolved to make a careful investigation of all the specimens at my disposal, in order to determine whether any facts could be discovered which would show it to be either certain or probable that the calcareous shell with its organic contents and the siliceous spicules all three combine to form one organism.

* Annals, ser. 3. vol. ii. p. 386.

There were evidently three possibilities to be taken into consideration here:—

1. *Polytrema* might be a Sponge with a reticulated calcareous skeleton, forming a network like the horny substance of the officinal sponge. Within the gaps of this network would be the organic sponge-substance which forms siliceous spicules.

2. *Polytrema* might be a Polythalamian. The organic substance within the calcareous skeleton would then be a Rhizopod-body, and the siliceous spicules must have penetrated accidentally, or been eaten, or derived from a Sponge living parasitically in the Polythalamian.

3. The structure might, like *Carpenteria* in the opinion of Gray and Carpenter, represent a transitional form between Sponges and Polythalamia, inasmuch as the calcareous walls possess Foraminiferous structure, but the body of the animal is allied to the Sponges in its faculty of producing siliceous spicules.

As regards the first possibility, the preparation of thin sections of the calcareous mass shows that it does not consist of calcareous rods anastomosing in a netlike form like the horny skeleton of the common Sponge, but of lamellæ which enclose a system of anastomosing chambers nearly similar in form and size, and, further, that these lamellæ (the walls of the chambers, as has already been stated) possess an exquisite Foraminiferous structure. A thin section of *Polytrema*, perpendicular to the surface and viewed by transmitted light, is shown in Pl. VII. fig. 3. The colour of the calcareous walls is reddish, even in thin sections. They are all penetrated by the ordinary pore canals of the Polythalamia, which usually run perpendicularly and by the shortest course towards the surface. The thickness of the calcareous walls varies, although no definite rule could be detected. In fig. 3 a thicker calcareous wall runs from *a* towards *b* on the surface of the section of *Polytrema*; but similar thick walls are also frequently met with through considerable spaces in the interior of the structure. In very thin sections a stratified structure may be detected, especially in the thicker walls; and, corresponding with this, the canals of the wall exhibit a peculiar division into segments*, which may be perceived very distinctly, after the solution of the calcareous matter, in the membranous tubes which occupied each canal (fig. 9).

The pore canals of the surface are very closely approximated, being at an average distance of 0·009 mill. from each other. In the interior septa, on the contrary, they are often much further apart. The width of the canals themselves is 0·004–0·006 mill.,

* Figured in the same way by Carpenter in *Carpenteria*, Phil. Trans. 1860, pl. 22. fig. 15.

which is not unimportant for the determination of the species. Thus, for example, *Acervulina acinosa* is very clearly distinguished from *Polytrema miniaceum* by the greater diameter of its canals, which usually measure 0·012 mill.

If the calcareous matter be dissolved by dilute muriatic acid from specimens which have been preserved in spirits, the organic substance occupying the chambers is obtained free, forming a true and connected cast of the internal system of cavities. From these casts it can be proved, much better than from sections which never open out more than one plane, that the interior of the calcareous shell is divided into chambers (figs. 5, 6, & 7), which are connected together by siphons. Especially at the base and in the centre of the *Polytrema* the siphons are very sharply divided from the chambers, whilst towards the surface the siphons are frequently so dilated that they attain the diameter of the cavities of the chambers, as is shown in the representation of the cast of a small portion of the inner space of the rind of a *Polytrema* in fig. 4. Although no regularity is to be detected in the general arrangement of the chambers, the portion of a natural cast of *Polytrema* shown by me in fig. 6 deserves especial consideration. This was brought to light by breaking up a preparation treated with muriatic acid. The perfectly irregular contents of the superficial chambers having been removed, an unmistakably spiral arrangement in the more deeply seated chambers made its appearance. The connexion with the rest of the mass was broken; so that only the six chambers figured could be seen in their natural connexion. The finer structure of the membrane and contents of these segments left no doubt that the regularly grouped masses in figure 6 and those represented in figures 5 and 7 really belonged to the same specimen. This discovery agrees with that described by Carpenter in *Tinoporos**

The organic substance remaining after the treatment of specimens of *Polytrema* preserved in spirits consists of an external membrane and a tenacious brownish-red substance, rich in strongly refractive granules and drops, which render it opaque. Both the envelope and contents precisely resemble the brownish-red contents of the chambers of many Polythalamia. I have figured this in plate 3. figs. 11 & 12, plate 5. figs. 12 & 13, and in other parts of my work on the Organization of the Polythalamia, and indeed partly from spirit-specimens, so that the figures cited are directly comparable with those here given of *Polytrema*. The organic envelope of the contents of the chambers of the Polythalamia is described by me as follows, at p. 15

* Phil. Trans. 1860, pl. 21. fig. 11, and pl. 22. figs. 2, 3 & 4.

of the same book:—"The calcareous shell of the Rhizopoda is lined by a delicate organic membrane. If a *Rotalia*, *Rosalina*, or *Textularia*, living or preserved in spirit, or dried with its organic contents, be dissolved in dilute acid, there is observed within the above-mentioned organic foundation of the calcareous shell, a thin, but sharply contoured, homogeneous membrane, of a more or less brown colour, which lies close to the former, and, like it, is penetrated by pores. This uniformly lines all the chambers, and is continued through the siphons of the septa from one to the other. It is only in the last and youngest chambers, which during life are nearly colourless, that this membrane is so delicate that one might suppose it to be formed only simultaneously with the reception of colouring matters into the animal contents." This description applies perfectly to the organic lining of the chambers of *Polytrema* as here represented (fig. 8). It forms a delicate, brownish, empty tube, occupied only at its lower part with granular remains of the body of the animal, which remained after the solution of the lime, but is not the organic foundation of the shell itself. The latter contains so little organic substance, that, in dissolving it in acids, I never could succeed in obtaining a coherent portion of membrane. But the place which it occupied, and its thickness, may nevertheless be recognized in shells which have been carefully dissolved, and, indeed, in the organic linings of the pore canals which penetrate the latter. As the cavities of the chambers are limited by a dense organic membrane, the tubules which pass straight through the thick shell, and which are rather wide in *Polytrema*, are also lined with a similar membrane. Some such delicate tubes, isolated by the acid, are shown in figure 8, lying partly upon and partly near the membrane; others, in much greater number, are shown in their natural position in figure 4; and figure 9 represents some similar tubes, of remarkable length. They therefore correspond with the pore canals passing through the shell, represented in figure 3. They exhibit the same difference of length according to the thickness of the shell, and show the same peculiar segmentation, which seems to be connected with the stratification of the shell.

The brownish-red contents of the chambers, lastly, show no other structure than that which I have described for the contents of the shells of *Polythalamia*.

If, however, from the structure of the calcareous walls of the shell of *Polytrema*, and from the nature of its contents, the notion that we might have in it a Sponge with a reticular calcareous framework is to be regarded as set aside, and it is rather proved that *Polytrema* approaches the *Polythalamia* in every respect, we have still to settle the question as to how the siliceous

spicules get into the interior of the chambers. Are they produced in the *Polytrema*? Have we to do with a transitional structure between Rhizopods and Sponges, according to the notion of Gray and Carpenter? or are the siliceous spicules foreign bodies in the Polythalamian, either introduced as food or belonging to a parasitic Sponge? With regard to this question, the following observation is to be made:—The siliceous spicules never occur in the above-described yellowish-brown animal contents of the *Polytrema*, which are to be regarded as the Polythalamian body, but always *beside* these, in an extremely destructible, transparent, colourless, finely granular substance, which shows but little coherence, and is consequently distinct from the former. During the solution of a *Polytrema*, with its animal contents well preserved, in a dilute acid, the difference between the two substances (the dense yellowish-brown one, and that which contains the spicules) at once strikes the eye. The latter is, however, usually so extremely small in quantity around the siliceous spicules, which frequently lie as if quite uncovered, that it is impossible to prepare it in connexion. It breaks up as the spicules separate from each other; and only traces of it adhere to individual spicules or groups of spicules (fig. 10). It is, moreover, of particular importance that *by no means all specimens of Polytrema contain spicules*, and that, when these do occur, they usually occupy only the peripheral chambers. The twelve spirit-specimens of *Polytrema* which I examined by means of dilute acids gave the following results:—Two of them had no trace of siliceous spicules; all the chambers were completely filled with the yellowish-brown substance, which diminished a little in intensity of colour towards the periphery. Three specimens contained the remains of the yellowish-brown substance only in the more deeply seated layers; nearly all the chambers were full of siliceous spicules and the small quantity of colourless organic substance belonging to them. All the rest likewise contained siliceous spicules, but only in the peripheral chambers, and often only in one part of them; the greater part of the interior system of cavities was filled with the brown substance, as shown in figs. 4–7. The siliceous spicules therefore may be entirely wanting; and when they occur, they never lie in the true Polythalamian substance, but rather diffuse themselves, with displacement of the latter, from the periphery towards the deeper parts; moreover they are imbedded in an organic substance which does not appear to belong to the Polythalamian body. The nature of the last-mentioned substance certainly cannot be positively determined. It might possibly be colourless Polythalamian substance. But, in opposition to this, we have, in the first place, its want of solidity, its want of co-

hesion after the solution of the calcareous shell, and then its diffusion, in certain cases, even into the central parts of the shell. *Polythalamia* which exhibit a yellowish-brown coloration of the body in the central chambers always, according to my observations, present the same or nearly the same colour through all the chambers, with the exception only of the few last-formed ones. This was also the case in several *Polytremata* which contained no siliceous spicules, and as to the true Polythalamian nature of which there could be no doubt. Now, may the originally brown substance become colourless again during the appearance of these spicules? Our previous experience furnishes no reason for such a supposition; and therefore we must argue against it, so long as another course is open to us.

Of such, three present themselves:—Either the siliceous spicules have penetrated accidentally, or they have been taken in as food, or, lastly, they belong to a parasitic Sponge. I have already mentioned that many specimens of *Polytrema* exhibit erosions of their surface, especially at the apices of the comb-like or tooth-like elevations—apertures by which a glimpse is afforded of the inner system of cavities. The siliceous spicules are always to be found in abundance at such spots, in the chambers nearest to the orifice. Frequently, as was observed by Krohn at Nice, the spicules project freely from the apertures, so as to be detected at once by the microscope. The siliceous spicules, if not produced in the Polythalamian body, have certainly penetrated from the apertures. It might be in vain to attempt to prove that they have not penetrated accidentally, or been taken in as nourishment. But no probable grounds can be adduced for either of these views. How could sponge-spicules, however numerous they might be in the water surrounding the *Polytremata*, find their way into the innermost chambers of the labyrinthic system of cavities, still at least partly filled with organic substance? Must not the filling of the peripheral chambers with such spicules, crossed in all directions, prevent the penetration of the latter into the deeper layers? And if Sponges were the favourite food of the *Polytremata*, how could adherent Polythalamia get at adherent Sponges in order to devour them?

There is consequently no reason why we should not embrace the last possibility, and assume that *Polytrema* is infested by a parasitic Sponge. That Sponges bore into many calcareous structures, and live like parasites, is well known. The genus *Cliona*, upon which Lieberkühn* has recently published some exact observations, is one of these boring Sponges. Its extraordinary diffusion appears from the fact that on many coasts

* Müller's Archiv, 1859, p. 515.

(Heligoland; Northumberland, according to Hancock) it is scarcely possible to find an oyster-shell or a piece of limestone which is not completely riddled by *Cliona*. In any case the parasitism of a Sponge in *Polytrema* presents nothing remarkable; and the next question is, whether the form and arrangement of the spicules support the notion that they belong to a Sponge like *Cliona*. Of the spicules of *Cliona celata*, which occurs in particular abundance in oyster-shells on Heligoland, Lieberkühn says that they are knobbed at one end, but that "frequently a very short point projects beyond the knob; and an inflation of the middle of the spicule also occurs, although extremely rarely." This is all that I can learn as to the forms of the spicules in the *Cliona*. Unfortunately it does not suffice for the discrimination of a siliceous Sponge; for knobbed spicules are common to many species, and often associated with ordinary awl-shaped spicules. The greater part of the spicules of our *Polytrema*-Sponge are subulate at both ends, as shown in Pl. VII. fig. 10. Many are broad; but the small forms resembling a clasp or cramp (fig. 10 *a*) are rare. *Capitate spicules* also occur, in which the axial canal, which is wanting in no siliceous spicule, presents an inflation in the knob. All the spicules are comparatively short, so that they extend at the utmost through two or three chambers of the *Polytrema*. A few fragments of larger spicules that I have seen, as also the extremely rare and likewise fragmentary calcareous spicules which are sometimes observed, I should regard as accidental admixtures. The short subulate spicules frequently lie parallel to each other in groups, as they are found *in situ* in Sponges.

The preceding statements suffice, in my opinion, to prove that, when siliceous spicules occur in the shells of Polythalamia, together with the organic contents of the chambers, the notion that in such cases we have before us transition forms between Foraminifera and Porifera has but little probability in it. The question now is, whether, in the case of *Carpenteria*, in which, according to Gray and Carpenter, a Foraminiferous structure of the calcareous shell and an occupation of the chambers by siliceous spicules also occur, there is any more reason to uphold the view promulgated by the English zoologists. Carpenter's description of the Polythalamian named after him, which is found living parasitically upon various marine productions, and especially numerous upon a fragment of a *Porites*, is, like all his works upon Polythalamia, so careful and accurate that we can obtain from it a perfectly clear idea of the structures in question. I am therefore the more confirmed in my opinion, because there does not appear to me to be the least reason for conceiving the relation between the sponge-spicules and the calcareous shell in

Carpenteria otherwise than in *Polytrema*. The calcareous shell in both cases is completely Foraminiferoid. The siliceous spicules lie scattered in the chambers, and are enveloped by but a small residue of organic substance. The *central chambers* (and this is of particular importance) were filled, in *Carpenteria*, also with a *firmer yellowish-brown substance containing no spicules*, exactly as in *Polytrema*. Lastly, the form of the spicules, according to Carpenter's figures (*l. c.* pl. 22. fig. 16), agrees almost exactly with that of those found in *Polytrema*, inasmuch as they are either pointed at both ends or knobbed at one end, bowed, and of small size.

As might have been expected, it occurred to Carpenter also that the spicules might be referred to a Sponge living parasitically in the Polythalamian. But, in finally coming to the conclusion that both belong to one organism, he lays particular stress upon the discovery of the above-mentioned yellowish-brown organic substance in the cavities of the central chambers, regarding this as true sponge-substance, without spicules indeed, but too dense and firm to be taken for the sarcode-body of a Polythalamian. Here Carpenter is in error. As I have already stated, from innumerable examinations of Polythalamia and Sponges, both dry and preserved in spirits, the substance of the Polythalamia is much denser, firmer, and more resistant than the organic substance of the Sponges. With the exception, of course, of the horny substance of the horny Sponges, the organic envelope of the sponge-spicules breaks up and becomes decomposed with such remarkable ease and rapidity that I have never succeeded with spirit-specimens of Sponges, even when I had myself put them quite fresh into spirit, in isolating moderately large coherent portions of the organic substance, or making any investigations into its nature. In Polythalamia, on the contrary, in which the organic substance is so resistant that it remains capable of life for weeks even in the midst of decaying substances, and that they may be kept alive for months far more easily than any other marine animals, the action of spirit or desiccation causes such a hardening that the contents of the chambers may be isolated precisely in the state which Carpenter adduces in opposition to their Polythalamian nature.

For this reason I cannot regard the conditions in *Carpenteria* otherwise than as in *Polytrema*, and therefore believe that the boundary between Polythalamia and Sponges, which has hitherto been considered as a very sharp line, must still be maintained in all its integrity.

Supplementary.

In combination with W. K. Parker and T. Rupert Jones, two naturalists who have made themselves celebrated by their researches upon Foraminifera, Dr. Carpenter has just published a great work, through the medium of the Ray Society, under the title of 'Introduction to the Study of the Foraminifera.' In this (pp. 235 *et seq.*), *Polytrema*, which was only mentioned incidentally by Carpenter in his previous works, is described in detail, and illustrated by figures (pl. 13, figs. 18–20). During a visit which I lately paid him in London, Dr. Carpenter had the kindness to show me his rich collection, including his preparations of *Polytrema*. Although his specimens were obtained from the South Sea, and mine from the Mediterranean, and his exhibit more variation than mine in their external form, I do not think that there can be any doubt as to their specific identity. Carpenter has arrived at the same result as myself—namely, that *Polytrema* is a Polythalamian. His investigations have, however, been made only with dried specimens, and have no reference to the organic contents of the chambers. Carpenter had no inducement to discuss the question whether *Polytrema* produces spicules, and is thus allied to *Carpenteria*, as his specimens contained *no spicules in their interior*. Nevertheless he mentions having seen specimens with the surface entirely covered with a parasitic Sponge, the spicules of which, however, penetrated scarcely, if at all, into the interior of the chambers. By this means Carpenter establishes a sharp distinction between *Polytrema* and *Carpenteria*. If in the former there could be no doubt as to the parasitic nature of the Sponge, as to the second Carpenter still adheres to Gray's opinion that the sponge-spicules are produced in the interior, and that *Carpenteria* is consequently a transition-form between Sponges and Foraminifera. Perhaps my observations upon *Polytrema*, which indicate the remarkably close affinity between that genus and *Carpenteria*, may serve to shake Carpenter's faith in his opinion.

Upon the systematic position of *Polytrema* among the Polythalamia I have hitherto said nothing, except mentioning its near affinity in appearance with my genus *Acervulina*. The *Acervulinidæ*, which form a peculiar family in my System of the Polythalamia as established in 1854, are characterized chiefly by the irregularity of their growth, in consequence of which they appear like a misshapen aggregation of chambers deposited one upon the other without any definite system. I was indeed aware that in several families, especially that of the *Rotalidæ*, an irregularly growing form may be produced from a Polythalamian which was at first regularly spiral; but these, from their com-

paratively great transparency, were always easily referred to the Rotalide type, whilst in the form which I named *Acervulina* no such spiral nucleus had been detected; so that, without forgetting that the boundaries of the families of the Polythalamia generally are very artificial, and that every system cannot be satisfactory in every direction, I did not hesitate to form a distinct family for the sake of the preliminary revision. Nevertheless it appears that the irregular increase in age occurs more frequently than was previously supposed in species which showed regular spiral shells, and that a spiral nucleus is to be detected in the centre of many apparently quite irregular aggregations of chambers, which were therefore true *Acervulinae*. Hence it would be better, with Carpenter, to adopt the irregular growth only in the generic or specific diagnoses, and to give up the family *Acervulinidae*. With this I perfectly agree, only remarking that in *Acervulina acinosa*, the typical form on which the genus was founded by me, no spiral or other regular commencement has been detected, and that, for all such forms, the genus *Acervulina* must still be provisionally retained. In Carpenter's system, *Polytrema* would come in the family *Globigerinidae*, near *Tinoporus*, on account of the spiral commencement (imperfectly seen even by that observer) and of its shell-structure. *Carpenteria* must then be reckoned among its nearest allies.

If I say a few words in conclusion upon the systematic division of the Foraminifera proposed by Carpenter, I can only give my general approval of it. It is distinguished from previous attempts of the same nature by its placing in the foreground, for the definition of the principal groups and families, certain peculiarities of the shell-structure which have hitherto been either employed only for the determination of genera and species, or not sufficiently recognized, whilst that which has hitherto furnished the main classificational character—the arrangement of the chambers—has only a secondary importance attached to it. There is no doubt that the two suborders formed by Carpenter, *Foraminifera imperforata* and *F. perforata*, form sharply differentiated and in themselves coherent groups. It must, however, be expected that, however natural the classification may be in general, in detail many apparently unnatural separations may occur. I instance only the dismemberment of the genus *Cornuspira*, one species of which has a brown, translucent, imperforate shell, and the other a hyaline perforated one, although perfectly similar as regards the internal cavity, the direction of the spiral, the size, &c.; so that the two species now naturally stand, with different generic names, in two different suborders.

The six families which Carpenter distinguishes are, of the Imperforata—1, *Gromida*, with a membranous shell; 2, *Milio-*

lida, with a calcareous porcellanous shell; and 3, *Lituolida*, with a calcareo-siliceous shell containing sand-grains: of the Perforata—4, *Lagenida*, with very fine pore canals; 5, *Globigerinida*, with larger pore canals; and 6, *Nummulinida*, in which, in addition to the ordinary pore canals, never usually very fine, there is a system of peculiar cavities and canals, giving the shell a very complicated structure. The families are sometimes very large, and might well be divided into subfamilies, which would nearly agree with the families established by me,—for example, Carpenter's *Miliolida* into the true *Miliolida*, the *Peneroplida*, *Soritinæ* (*Orbitulitinæ*), *Alveolinida*, &c. From the wonderful perseverance and great skill which Carpenter has shown in his researches upon the shells of the Polythalamia during many years, and considering the enormous amount of materials, consisting of the most various forms from every zone, which he had at his disposal, one can understand how he comes to undervalue a little the works of his predecessors, and especially mine, in so far as they treat of the shell-structure. Indeed it was the chief object of my researches to ascertain the exact nature of the animal body which inhabits and forms the shell, for which reason I confined myself especially to the forms observed by me in a living state, and their nearest allies. Moreover, although I was assisted by many of my friends, I found it impossible to bring together all the species, as I desired and indeed required for the elaboration of a systematic revision. For example, I was almost entirely destitute of the living species of Carpenter's *Nummulinida*, and thus had not the opportunity of seeing the system of ramified tubes first described by Carter, as stated at page 15 of my book. Nevertheless my observations upon the shell-structure are not so scanty as Carpenter seems to suppose. In opposition to his repeated assertion*, that I have too much neglected the investigation of the shell-structure, and confined myself to the examination of the animal, I may be allowed to urge that, independently of the representations of the shell-structure of the species observed living by me, such as *Polystomella strigillata* (pl. 4 & 5. figs. 2, 6, 7, 9, 10), *P. gibba*, *P. stella*, *P. borealis*, and *P. venusta* (pl. 6. figs. 2, 5, 8), of which I think I may assert that they are not exceeded by Carpenter's, there are in various parts of my work (especially in the chapter "On the Shells of the Marine Rhizopoda," and in section iii. p. 37) a great number of remarks, founded upon personal observation, as to the structure of numerous exotic Rhizopod-shells, such as the *Sori-*

* Phil. Trans. 1856, p. 187; Introduction to the Study of the Foraminifera, p. 10.

tina (*Orbitolitina*), *Orbiculina*, *Alveolina*, *Siderolites*, *Calcarina*, *Fusulina*, &c., which Carpenter has nowhere quoted. Even the foundations of Carpenter's new system of the Foraminifera are to be found expressed in my book (p. 12), in the following words:—
 "In respect of the finer structure of the shell, the calcareous Foraminifera may be divided into *two series*, namely, into those which have the shell perforated throughout with numerous fine apertures or canals, and those in which the shell appears solid and homogeneous."... "Sufficiently transparent forms, or thin sections of opaque ones, when examined under the microscope by transmitted light, either appear as colourless as glass or show a brown coloration. To the latter belong all the solid and not finely porous shells, and therefore the whole of the *Miliolida*, the *Ovulina*, *Cornuspira planorbis*, and the *Peneroplida*." To the same category I referred also *Orbiculina* and *Sorites* (*Orbitolites*), although here I erroneously supposed their shell to be perforated by small apertures, which, as Carpenter rightly asserts, they do not possess. In opposition to these *calcareous-shelled* Rhizopods, I placed the only *siliceous-shelled* species then known, the *Poly-morphina silicea**, observed by me at Ancona. Carpenter might consequently have sought the first sure foundation of his family *Lituolida* also in my observations, which, however, appear to have been quite unknown to him, as also my later communications upon a form resembling *Nonionina*, with a granular siliceous shell †. The latter possesses a particular interest, inasmuch as it contained in its interior numerous small globular shells agreeing in structure with the large shell, and which, in accordance with my observations on the reproduction of the *Miliolida* and *Rotalia*, must be regarded as young. If these, therefore, form a siliceous shell while still within the body of the parent, Carpenter's notion that the siliceous particles of the shells of Foraminifera are *always* derived from the surrounding sand ‡ must require modification.

However, I must repeat that I welcome with pleasure the classification of Foraminifera proposed by Carpenter, as a real step in advance. That it is a natural and true expression of our knowledge of the Foraminifera, which has made such consider-

* Ueber den Organismus der Polythalamien, pp. 9, 11 & 61. Reuss has since (Sitzungsber. der böhmischen Ges. der Wiss. zu Prag, Nov. 28, 1859) justly called attention to the fact that the species would be better referred to the genus *Bulimina*, in which many sandy siliceous forms occur. I leave it to Reuss to give the species a suitable name.

† *Nonionina silicea* (Müller's Archiv, 1856, p. 171, pl. 6. fig. 4) will also have to receive a new name, and must be referred to the genus *Lituola* or *Haplophragmium*, Reuss.

‡ Introduction, &c., pp. 47 & 140.

able progress during the last ten years, is strikingly shown by the fact that the most experienced student of the Foraminifera in Germany, Professor Reuss, of Prague, in his most recent works, proposes a systematic distribution of these animals according to exactly the same principles as those adopted by Carpenter. Reuss's chief work, "Entwurf einer systematischen Zusammenstellung der Foraminiferen," is printed in the Number of the 'Proceedings of the Academy of Sciences at Vienna' for October 1861, and is cited by Carpenter in the bibliographical section of his last work (p. xxi. no. xci. a), but appears to have reached him after the impression of the text, as it is nowhere quoted in the latter. In it (see especially the 'Nachschrift,' p. 394) the Foraminifera are divided, as by Carpenter, into those with *non-porous* and those with *porous* shells; and, as Reuss excludes the *Gromida*, there remain two groups in the first section,—(1) those with sandy siliceous shells; (2) those with compact porcellanous shells. In the second group Reuss distinguishes—(1) those with finely porous, hyaline calcareous shells; (2) those with manifoldly (?) porous calcareous shells; (3) those with calcareous shells permeated by ramified systems of canals. It is evident that the systems of Carpenter and Reuss perfectly agree. In its further development, however, I am inclined to prefer that of Reuss, as he distinguishes *smaller* families, more closely following the necessities of the zoologist and the previous systematic works, and, I believe, agreeing better with nature.

EXPLANATION OF PLATE VII.

- Fig. 1.* A specimen of *Polytrema miniaceum* from the surface of a Crab; magnified 15 diameters.
- Fig. 2.* Part of the surface of the same *Polytrema*; magnified 300 diameters, to show the apertures of the pore canals.
- Fig. 3.* Thin section through the calcareous wall of *Polytrema*; magnified 300 diameters.
- Fig. 4.* Part of the animal-body of a *Polytrema* preserved in spirits, laid bare by muriatic acid. In the place of the thick calcareous wall, only the membranous linings of the pore canals are retained *in situ*.
- Figs. 5, 6 & 7.* Parts of the body similarly prepared. *Fig. 6* shows the spiral arrangement of the chambers, probably the first-formed part of the *Polytrema*.
- Fig. 8.* Membranous lining of the chambers without the body, or with only a few traces of the latter; isolated by acid.
- Fig. 9.* Two membranous linings of pore canals, with many indications of joints.
- Fig. 10.* Siliceous spicules from different chambers of *Polytrema*.